# XVI. COMMUNICATIONS BIOPHYSICS

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## A. ELECTRICAL RESPONSES TO CLICKS AND TONE PIPS AS RECORDED FROM THE AUDITORY CORTEX

We are studying the responses to acoustic stimuli which can be recorded at the surface of the auditory cortex of the anesthetized cat. Presented below are results recorded simultaneously from two points, 1 cm apart, one in Area I and the other in Area II, on the middle ectosylvian gyrus.

### 1. Responses to Clicks

Figure XVI-1 illustrates the response to the same click stimulus, 40 db above threshold, recorded from Area I (lower trace) and Area II (upper trace). Both traces begin with the delivery of the stimulus, show some activity (attenuated at these electrode locations) of subcortical auditory centers, followed by the classic triphasic (- + -) cortical response. Both cortical points swing surface-negative together, whereas the surface-positive response (peak) leads by approximately 0.5 msec in Area I. This confirms a recent finding by Mickle and Ades.

As the click stimulus is attenuated towards the threshold of Cat-322 this 0.5-msec latency difference between the two points is increased to 1 msec. In addition, the response amplitudes $A_1$ and $A_2$ are reduced. Figure XVI-2 illustrates the unequal changes (with click intensity) of $A_1$ and $A_2$, especially for the response from Area II.

### 2. Responses to Tone Pips

Sample responses from the same two cortical points to brief (10-msec) tone pips are presented in Fig. XVI-3.

The usual analysis of the cortical response has aimed at identifying the positive and negative components of the response with events or structures within the cortex. Many investigators, for example, have manipulated these response components by applying procaine, strychnine, thermocoagulation, and the like, to the cortex itself.

Since it is possible to alter the response potentials differentially merely by changing the intensity or frequency of the acoustic input to the ear, it would seem that analyses which omit consideration of the stimulus parameters are incomplete.

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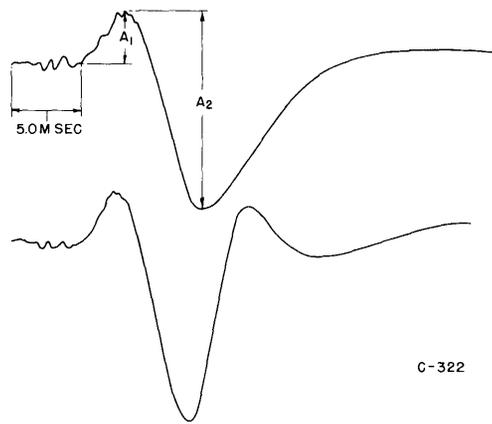*From the Neurophysiological Laboratory of the Neurology Service of the Massachusetts General Hospital.

Fig. XVI-1

Responses to the same click stimulus from audi-
tory Area I (lower trace) and Area II (upper trace).
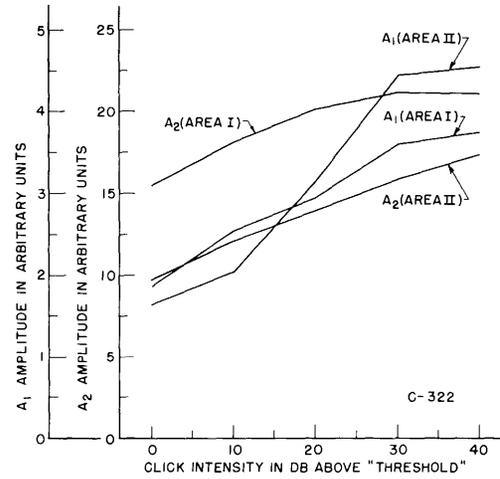(Negative up in this and in Fig. XVI-3.)



Fig. XVI-2

Amplitude growth of $A_1$ and $A_2$
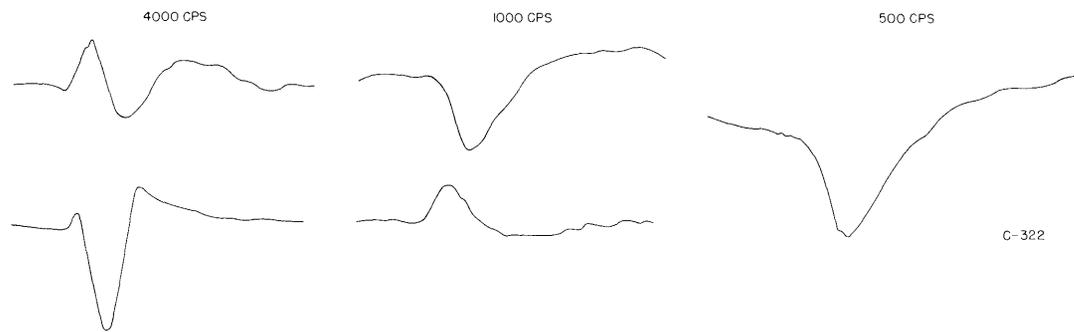with click intensity.



Fig. XVI-3

Responses from the same cortical points as those in Fig. XVI-1
to three frequencies of tone pips.

## B. ANALOG CORRELATOR FOR ELECTROENCEPHALOGRAPHY

Construction of the mechanical parts of the magnetic delay drum is nearing completion, and its associated electronic circuits are under construction. The automatic control system for recycling the magnetic tape between computation of successive points on the correlation curve is also under construction.

This device is modeled after a similar system that has been used in conjunction with the M.I.T. digital correlator, with modifications to accommodate the present system.

The drum-advance mechanism is designed to operate independently of the tape recorder if desired, for computation of correlograms from signal generators, noise sources, and the like, retaining the multiple-step feature for these alternate sources.

Automatic operation of the correlator is not only of great convenience; it is also instrumental in making the computational process as short as possible (one or two hours) so that major errors are not introduced by drift of the various dc stages of the correlator.

An autocorrelation function of a 30-second sample of electrical potentials recorded from a cat's auditory cortex (ectosylvian gyrus) is shown in Fig. XVI-4. The cat was under light nembutal anesthesia. The pen-and-ink record made by an Offner electro-encephalograph was analyzed by means of the manual correlator of the M.I.T. Servomechanisms Laboratory. Though a Fourier transform of this correlogram is not yet available, the graph exhibits at least two kinds of periodic activity: one at approximately 15 cps and another of lesser amplitude of approximately 4-5 cps. The 15-cps activity does not persist as long as the slower activity. At the longest delays used, machine noise becomes sufficiently important to obscure the analysis.

These findings may be interpreted as reflecting the well-known barbiturate bursts superimposed, at this level of anesthesia, on the cat's intrinsic 5-cps rhythm.
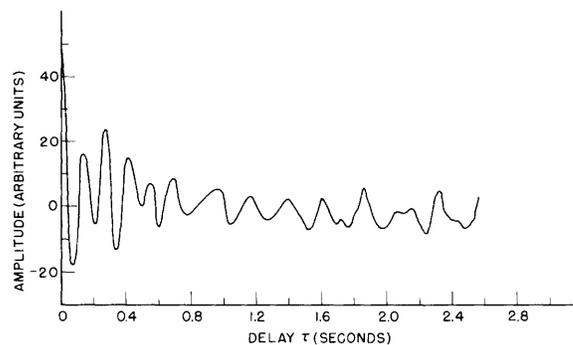


Fig. XVI-4

Autocorrelation of electrical activity from cat's (308) auditory cortex (ectosylvian gyrus). Nembutal anesthesia, 30-second sample.

Evidence from the correlogram suggests that maximum values of $\tau$ of the order of 2 sec will be adequate for the analog electronic correlator. With a record-playback ratio of 10 to 1 (60 inches/6 inches per sec) and maximum delay on the drum of about 190 msec, the maximum delay now planned is 1.9 sec. Longer delays will necessitate even slower recording speeds.

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## C. AUDITORY SENSITIZATION (ELECTROPHYSIOLOGICAL RESULTS)

Psychophysical experiments at the Harvard Psycho-Acoustic Laboratory have revealed a sensitization in the absolute threshold of pure tones after stimulation with relatively intense low-frequency tones. These studies used the Békésy audiometer in order to record continuously the absolute threshold of human subjects. Experiments on cats were conducted at M.I.T. in an attempt to obtain electrophysiological evidence for auditory sensitization.

In these experiments the test stimuli were short tone pips of 300 cps (6 cycles with a rise-fall time of 5 msec, presented every 2.4 sec). Tone pips were used rather than continuous tones, since responses to the latter exhibit a steadily increasing adaptation (or "equilibration"). Though adaptation is also present in the responses to tone pips,
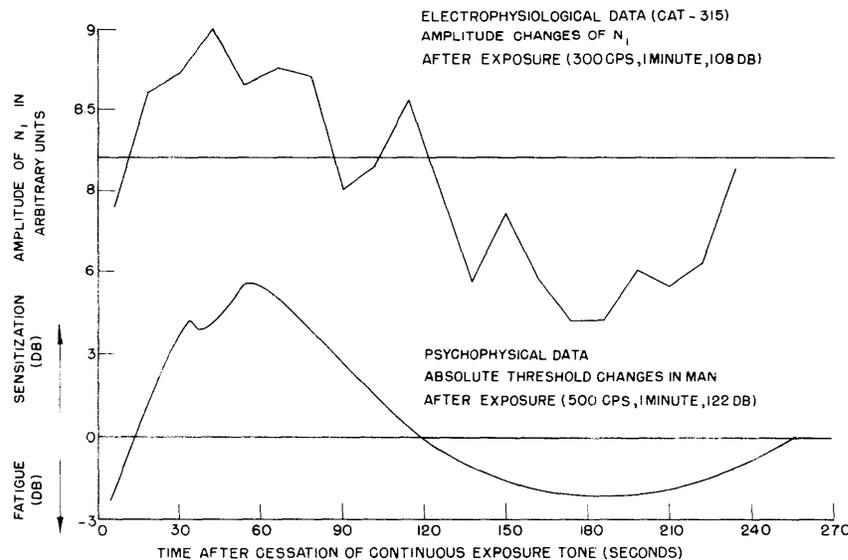


Fig. XVI-5

Auditory sensitization from electrophysiological and psychophysical data.

the stimuli are sufficiently separated in time to yield a fair measure of the responsive-
ness of the peripheral auditory system to supra-threshold stimuli.   Twenty pips (at
118 db,  above 0.0002 dyne/cm$^2$) were presented as test stimuli before the cat was stim-
ulated with a continuous tone of the same frequency (300 cps) for 1 minute at 108 db
SPL.   Following this prolonged stimulation, the same test tone pips at 118 db were pre-
sented every 2.4 sec for as long as 6 minutes.

Platinum wire electrodes, placed within a few millimeters of the cat's round window
and posterior-medial to it,  record the first neural response, $N_1$, to the pure tones.  At
appropriate locations one can detect $N_1$-responses to each cycle of the tone pip.  The
amplitude of the neural responses before and after the 1-minute stimulation was meas-
ured in arbitrary units.   The average (mean) amplitude of the 20 prestimulation
responses serves as a base line from which to measure sensitization and fatigue fol-
lowing continuous stimulation.

Figure XVI-5 shows the variations in amplitude of the $N_1$-response to the first cycle
of the post-stimulation tone pips as a function of time.  The heavy horizontal line  rep-
resents the mean amplitude of $N_1$ in the prestimulation test,  that is,  the base line.  Each
point on the curve represents the mean of five successive post-stimulation amplitude
readings.   The curve shows an initial decrease in the $N_1$ response,  then a sensitization
(the supernormality is significant beyond the 1-percent level by Fisher's Exact Test),
followed by a secondary fatigue.  Five similar sensitization curves have been obtained
on three different cats.  Figure XVI-5 also shows psychophysical data on the absolute
threshold changes in humans after exposure to 500 cps,  1 minute,  122 db (test tone was
a continuous 500 cps).   There appears to be a marked similarity between the time course
of the sensitization curve obtained electrophysiologically on cats and psychophysically
on humans.

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## D.  AN ELECTRONIC DEVICE FOR THE MEASUREMENT OF THE LATENCY OF "NEURALS"

The present technique for the measurement of the latency of neural components
recorded near the round window involves photographing the response and determining
the latencies by means of the microfilm reader.  This procedure is tedious and has the
disadvantage that there is a considerable interval between the actual experiment and the
time at which the data become available.  The device under construction will provide an
instantaneous measurement of the latencies,  allowing practically immediate evaluation
of the latency data.  This device will be called a neural latency monitor (NLM).

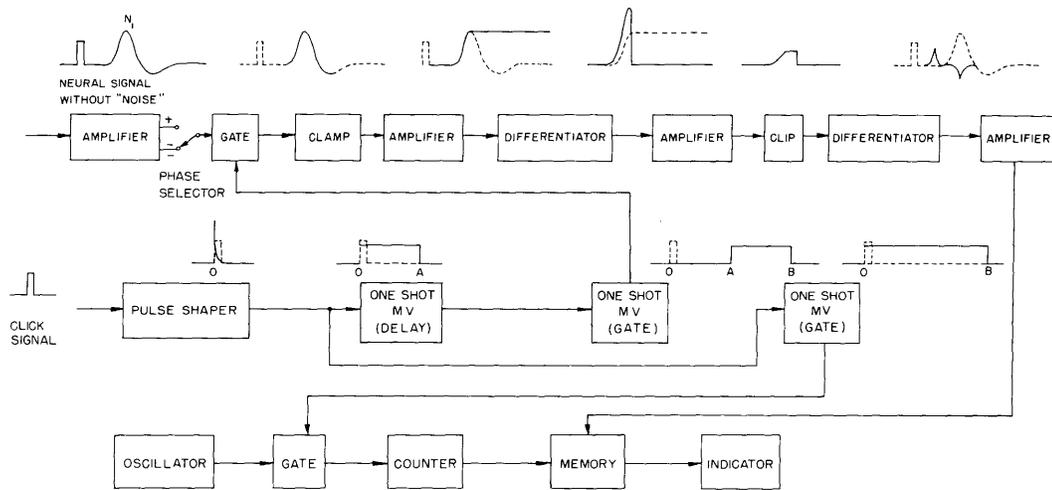The block diagram is shown in Fig. XVI-6.  A highly schematized response to an

Fig. XVI-6

Block diagram of the neural latency monitor.

acoustic click emphasizing the first neural component, $N_1$, is shown. The gate is opened at approximately 0.5 msec before the first neural. This delay time and the duration of the gating pulse are both adjustable. A clamp holds the amplitude of the latest, most negative excursion of the signal during the gating interval. This clamp signal is subsequently differentiated, clipped, and again differentiated. This procedure results in two pips of opposite polarity. Note that the second pip will occur at a time just before the neural potential exhibits a zero slope. Since the shape of the neural is more triangular than sinusoidal and since the amount of amplification following the clamp differentiator is limited only by noise generated after the clamp, this time difference between the most negative excursion of the last output pip can be made as small as necessary. This pip is used to trigger the memory circuit that follows the counter. The counter began its count at the time of the click stimulus, so that the count held by the memory circuit can now be read from the indicator.

The need for some memory scheme is brought about by the presence of noise and microphonic potentials in the response signal. The clamp holds to the most negative swings of the total signal and the following circuits generate negative pips corresponding in time to the zero slope points of these negative "pulses." Thus, the last pip generated while the signal gate is open corresponds to the neural, provided that the neural is a greater magnitude "pulse" than the other negative "pulse" in the signal. The neural is almost always greater than other parts of the response signal. An oscilloscope is used to monitor the response in any case, so that this condition can be checked. Since the memory circuit holds the count of the counter at the instant of each pip, the final count indicated corresponds to the latency of $N_1$.

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